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On Polyethylene Cable Failure, Electric Fields, Water Clusters and Ions

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Polyethylene high voltage cable insulation does frequently fail in the absence of voltage stabilizers (normally antioxidants). A main mechanism in cable degradation is water treeing, a phenomenom in which water forms tree-like structures inside the insulation. In a series of simulations the molecular mechanisms behind water treeing have been studied using an connectivity altering Gibbs ensemble Monte Carlo simulation method [1] to model the equilibrium of water molecules between a pure water phase and a polyethylene phase. Polyethylene has been modelled with united atom models, like TraPPE whereas water has been modelled using SPC and SPC/E models.

To model ionic impurities (from, e.g, the catalysts used in polyethylene production) in the polyethylene a NaCl ion pair was inserted into the simulation box. This led a dramatic increase in water solubility in the polymer and the formation of water clusters around the ions. If the distance between the ions was smaller than about 2 nm the the two clusters were united into one large cluster [2]. The effect of an additional electric field has also been investigated and the conclusion is that an applied field in the absence of ions has a minor effect but gives rise to a decreased solubility of water in the hydrocarbon phase at very high external fields (> 1 GV/m) – partially because of an increased ordering of the water in the pure water box. If, on the other hand, an electric field is applied to a system containing an ion pair water solubilities increase when the electric field is aligned with that between the ions (except at the highest fields > 1 GV/m)

A mechanism for the degradation of high voltage cables is proposed based on the above results.

[1] .E.Johansson, K.Bolton, D.N.Theodorou, P.Ahlström,

J.Chem.Phys.126, 224902 (2007)

[2] E.Johansson, K.Bolton, D.N.Theodorou, P.Ahlström, J. Chem. Phys. 127, 191101 (2007)

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